On the effects of attention to agent/recipient in collision events on the use of heuristics for relative mass judgements

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ON THE EFFECTS OF ATTENTION TO AGENT/RECIPIENT IN COLLISION EVENTS ON THE USE OF HEURISTICS FOR RELATIVE MASS JUDGEMENTS

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The purpose of this study is to examine how the instructed attention to agent/recipient in collision events affects the use of heuristics for relative mass judgements. About ten subjects of each gender were assigned to one control group (not instructed to pay attention to a specific object) and two experimental groups (instructed to pay attention to either agent or recipient), and asked to judge the relative mass in collision events. The results showed that the effects of attention were significant only for male subjects instructed to pay attention to agent: They often used the heuristic method based on the direction of agent movement, while most of the other observers used the one based on recipient speed, whether instructed to pay attention to agent/recipient or not. As to these findings, the effects of object of attention, gender, and their interaction were discussed.

Key words: collision events, relative mass judgement, agent, recipient, attention.

INTRODUCTION

We can easily detect various covert properties of objects and persons, based on kinematic patterns projected on our retinae. Michotte was one of the earliest and most famous experimental psychologists who dealt with such ability (Michotte, 1963; Thines, Costall, & Butterworth, 1991). In so many experiments, he displayed various collision events to his subjects to show that causality between agent (launching, entraining, or impinging object) and recipient (launched, entrained, or impinged-on object) was not inferred or reasoned through some calculation, but perceived as such.

Included in detectable covert properties so far examined in the following post-Michotte studies were not only dynamical properties, such as lifted weights (Bingham, 1987; Runeson & Frykholm, 1981, 1983), mass ratio (Kaiser & Proffitt, 1984; Todd & Warren, 1982; Runeson & Vedeler, 1993), naturalness of collision (Kaiser & Proffitt, 1984, 1987), and elasticity (Warren, Kim, & Husney, 1987), but also animacy,and even a person's gender or intention (Cutting, 1978; Cutting & Kozlowski, 1977; Johansson, 1973; Runeson & Frykholm, 1983). Generally, earlier researchers along this line premised the so-called "Kinematic Specification of Dynamics" (KSD) theory. In other words, it was assumed that these dynamic properties were perceived directly and veridically through kinematic information contained in proximal stimuli (Kaiser & Proffitt, 1984, 1987; Michotte, 1964; Runeson & Frykholm,

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1981,1983; for a recent research, Runeson & Vedeler, 1993).

Beginning with Todd and Warren's study(1982), however, recent researchs dealing with the human ability of relative mass judgements in collision events has proposed the heuristic theory - that heuristic method, based on the knowledge of the physical properties plays a major role in the perception of dynamic properties. Todd and Warren(1982) classified the heuristics used for relative mass judgements in collision events into three types as follows[2].

Final Speed Hypothesis (FS)

The object whose postcollision speed is the greater between agent and recipient is lighter[3].

Initial/Final Speed Hypothesis(I/FS)

If the recipient is launched at a greater speed after collision than the speed of agent before collision, then the recipient is the lighter[3].

Direction Hypothesis(D)

If the agent continues to go forward after collision, it is the heavier of the two[3].

Gilden and Proffitt(1989) made similar classifications, and proposed angle - and velocity-based heuristics which corresponded to Direction Hypothesis and Final Speed Hypothesis. We replicated the stationary condition of Todd and Warren's experiment(1982), where one stationary object(recipient) was shown to be struck and set in motion by a moving object(agent) (Sato, 1991). We found that similar heuristics were used.

The discovery of these heuristics inevitably led to the second problem of what factors determine the use of each heuristic method. Todd and Warren(1982) were also the first to refer to this problem. They argued that the Final Speed Hypothesis was often used when two moving objects collided, while the other, undetermined heuristic method sometimes led to errors when a stationary recipient was impinged on by a moving agent. Gilden and Proffitt(1989) asserted that a usable heuristic method was selected according to informational salience, and evidenced this assumption experimentally. In dealing with this problem, we discriminated between accessibility(regarding awareness of heuristics) and utility(regarding use of heuristics). Our experiments showed that accessibility to the Direction Hypothesis was affected by the displayed stimulus events, and that, even when accessible, it was not often used in relative mass judgements.

The purpose of this study is to examine the effect of attention to a specific object(agent or recipient) in collision events on the use of heuristics for relative mass judgements. We postulated that usable heuristics might be intimately associated with the objects of attention in collision, in that the subject(the object concerned) was different in three heuristics which Todd and Warren(1982) proposed - agent in Direction Hypothesis, recipient in Initial/Final Speed Hypothesis, and both in Final Speed Hypothesis. We will test this by replicating the stationary condition of Todd and Warren(1982), where agent is distinct from recipient.

2. Todd and Warren(1982) used the term "Hypothesis" as synonymous with "heuristic".
3. Todd and Warren(1982) did not use the term "agent" and "recipient." It might be partly because, in one of the conditions they simulated(called moving condition) two objects approached each other at the same speed and collided, in which case each object played both active(as agent) and passive(as recipient) roles.

Of course, we cannot deny the probability that manipulation of informational salience as in Gilden and Proffitt's study (1989), might facilitate attention to a specific object, but salience itself does not uniquely specify it.

For example, there may be some cases in our daily lives where we are, for some reason, forced to pay attention to an object, in spite of informational salience, or where the equality of salience between dimensions of information does not disambiguate our attention. Thus, we will simulate, by instruction, the conditions where either agent or recipient in collision events is firmly fixated by observers, and examine whether the use of the Direction Hypohesis (associated with agent) or Initial/Final Speed Hypothesis (associated with recipient) could be facilitated respectively.

EXPERIMENT 1

Experiment 1 was a partial replication of our previous study (Sato, 1991).

It was executed to confirm a) how relative mass could be judged with no instruction to pay attention to a specific object in the stationary condition of Todd and Warren's study (1982), where an initially stationary recipient was struck and set in motion by a moving agent, and b) to obtain control data for experiment 2, where attention was paid to agent or recipient by instruction.

METHOD

Subjects: Twenty under- and post-graduate students (ten males and ten females) participated. All of them had normal or correct-to-normal vision, and were unaware of the purpose of this experiment. Some of them were paid for their participation, but were not told of their compensation until after the experiment.

Stimulus: The stimuli were collision events of two squares made with the aid of a personal computer (NEC PC-9801RX), and displayed on a CRT monitor (NEC PC-KD882). Each frame duration was 67 msec, and each collision event lasted for 5.3 sec. Basic sequences of stimulus events were modeled after the stationary condition of Todd and Warren's study (1982), as shown in Fig. 1: The agent (impinging square) approached and collided with an initially stationary recipient (impinged-on square), and after collision, recipient was set in motion, and the agent either went forward or ricocheted backward. The parameters for collision were as follows.

M_A •••• agent mass
M_R •••• recipient mass
U_A •••• precollision speed of agent (constant)
V_A •••• postcollision speed of agent
V_R •••• postcollision speed of recipient

(Positive speeds mean rightward movement, while negative speeds mean leftward movement.)

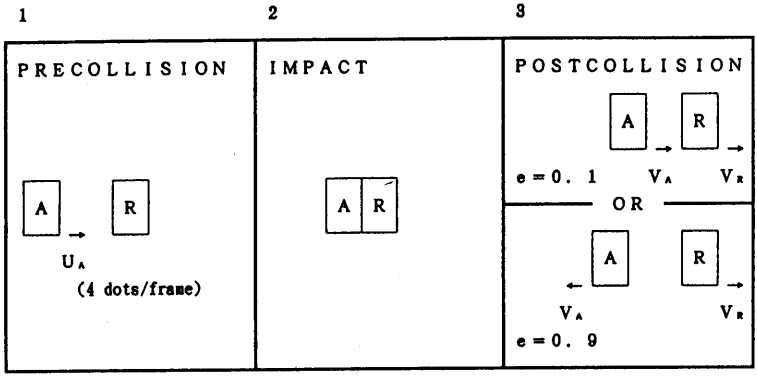

Fig. 1. Sequences of the stimulus collision event. (1) One square (A: Agent) approached to the other which was stationary initially (R: Recipient), (2) collided with it, and (3) either continued to go forward (upper panel) or ricocheted (lower panel).

Six collision events were designed on the combination of two elasticities ($e = 0.1, 0.9$) and three mass ratios ($M_A/M_R = 1/2, 2/3, 3/4$). Velocity values of each collision event are given in Table 1.

Table 1. Collision parameters for the experiment. The unit of velocities is dots/frame, and all the precollision velocities of A (U_A) are 4.

e / M_A/M_R	0.1	0.9
1/2	$V_A = 1.1$ $V_R = 1.5$	$V_A = -1.1$ $V_R = 2.5$
2/3	1.36 1.76	−0.6 3
3/4	1.54 1.94	−0.3 3.3

Procedure: Subjects participated in our experiment individually. In a darkened room, they sat at 57 cm from the CRT monitor for stimulus presentations, with their heads fixed on a chin rest. The perceived length of one side of a square was about 0.7 deg in visual angle (20 dots of CRT display). Their tasks were forced-choice judgements about which square (agent or recipient) looked heavier after one stimulus collision event was presented in each trial. In the instructions before the experiment, subjects were told about their task, and asked not to take external forces such as friction or air resistance into account, to base their judgements on perceptual impressions, not to persist in one heuristic method intentionally, and not to worry

about successively identical judgements. The important point here was that a specific instruction for attention to agent/recipient was not given to the subjects at all. After five-minutes of dark adaptation following instruction, the actual experimental session started without practice trials. One subject received 120 trials(six stimulus events * twenty repetitions) in an experimental session, and took a few minutes' rest after each block of 40 trials. After an experimental session ended, he/she was asked about the content of his/her heuristic method, the time it took to become aware of his/her heuristic method, and the object to which he/she paid more attention.

PREDICTION

Stimulus collision events in this study were made so that performances of relative mass judgements could differ according to the heuristics used or KSD theory applied. Figure 2 graphically represents our prediction of the percent of agents being judged heavier(percent "A (Agent) Heavier" plotted as a function of elasticity. If Todd and Warren's Initial/Final Speed Hypothesis(1982) was applied literally to our stimuli, it should lead to the same performance as predicted from the KSD theory, as shown in the left(ORIGINAL) panel of Fig. 2, because U_A was always greater than V_R (see Table 1). Our pilot study, however, showed that subjects using the Initial/Final Speed Hypothesis tended to vary their responses as shown in the right(MODIFIED) panel of Fig. 2. This was probably because, for the constancy of U_A, they based their judgements mainly on the relative magnitude of V_R within our stimulus events. That is, the recipient is judged to be the lighter if it is launched by the agent at the relatively greater speed in our stimulus events.

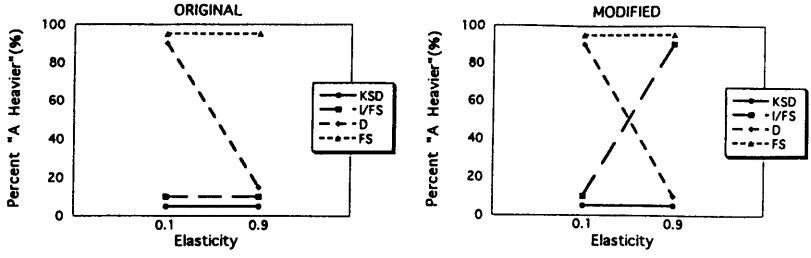

Fig. 2. The graphical representation of the percents "A(Agent) Heavier" predicted vis-a-vis the KSD theory and the use of three heuristics Todd and Warren(1982) proposed. The left(ORIGINAL) and right(MODIFIED) panel show the prediction derived from the literal and modified application of the Initial/Final Speed Hypothesis to our experimental stimuli respectively.

RESULTS

The results of experiment 1 are graphed in Fig. 3, with the percent "A Heavier" as a dependent variable. A three factorial ANOVA(between-subject variable: gender; within-

subject variable: elasticity, mass ratio) was run on these measures of probability. Significant factors and interactions were noted as follows: elasticity ($F(1,18) = 32.9$, $p < 0.01$), mass ratio ($F(2,36) = 8.44$, $p < 0.01$), and their interaction ($F(2,36 = 20.53$, $p < 0.01$). Analysis of this interaction revealed that the simple main effect of mass ratio was significant ($p < 0.01$) only when e = 0.9. Furthermore, by multiple comparison of the data when e = 0.9, it was shown that the percent "A Heavier" was lower when $M_A/M_R = 1/2$ than for the other mass ratios ($p < 0.05$).

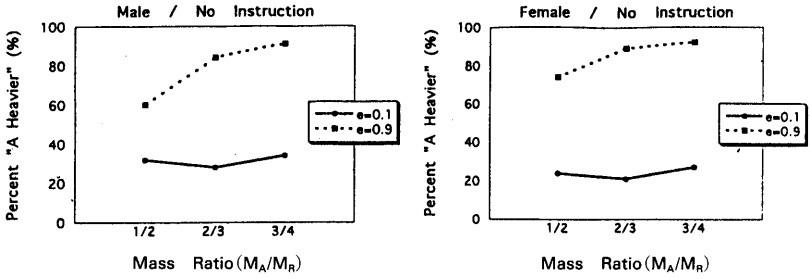

Fig. 3. Results of Experiment 1. The percents "A(Agent) Heavier" for each gender, obtained from the subjects who were not instructed to pay attention to agent or recipient (No Instruction group), are plotted as a function of mass ratio.

Figure 4 represents the percent "A Heavier" averaged over mass ratio as a function of elasticity. For each gender, the percent "A Heavier" was significantly above chance when e = 0.9, while below chance when e = 0.1.

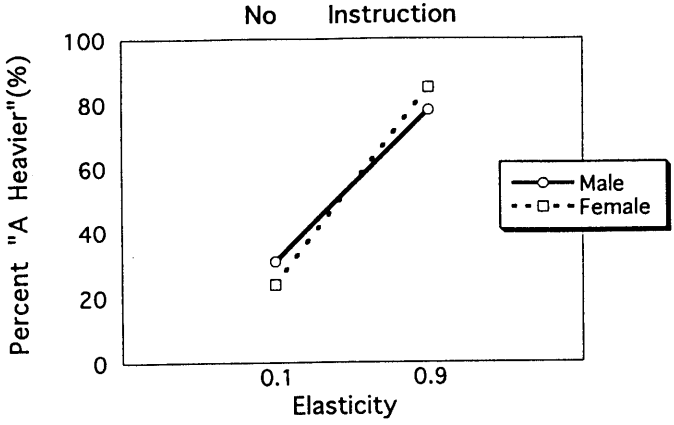

Fig. 4. Results of Experiment 1. The percents "A(Agent) Heavier," averaged over mass ratio, are plotted as a function of elasticity. This graph is made for comparison with the prediction shown in Fig. 2.

Discussion

Compared with our MODIFIED prediction shown in Fig. 2, the pattern of performance shown in Fig. 4 clearly shows that the Initial/Final Speed Hypothesis was used for relative mass judgements in most cases of this experiment.

This is the reconfirmation of the results of our previous study (Sato, 1991).

According to Gilden and Proffitt's salience-based theory (1989), the Direction Hypothesis should have been more applicable by the presence of the agent's ricochets in our stimulus events. However, as some subjects reported in debriefings, there might not be a sort of reference point or frame for the agent's slow movements, because of the darkness of our experimental room (making its ricochets difficult to find and reducing the salience of directional information). This problem will be discussed in more detail later in GENERAL DISCUSSION.

As to the effects of mass ratio, it was revealed from the results that the percent "A Heavier" when $M_A/M_R = 1/2$ was significantly lower than for the other mass ratio conditions, only when $e = 0.9$. It could be interpreted in the following two ways. First, since the mass ratio of $1/2$ was the most extreme value used in this experiment, correct answers ("the recipient is heavier") might have been easier to give than for the other mass ratios. If this interpretation is adopted, however, we should take the burden of proof regarding the reason for no significant difference due to mass ratio when $e = 0.1$.

Rather, it would be better to take another explanation into account based on Gilden and Proffitt's salience theory (1989): Direction-based heuristics might be easier to use when $M_A/M_R = 1/2$, because the agent in this case ricocheted at the greatest speed and thus provided the most salient directional information in our stimulus events when $e = 0.9$.

Experiment 2

The purpose of experiment 2 was to study the effects of attention to a specific object on relative mass judgements in collision events. To put it concretely, whether the use of the Direction Hypothesis or Initial/Final Speed Hypothesis could be affected by instructing subjects to pay attention to either agent or recipient was examined.

Method

Subjects: Forty-four under- and post-graduate students (twenty-two males, twenty-two females), who had normal or correct-to-normal vision, participated in experiment 2. None of them had participated in experiment 1, and all were unaware of the purpose of this experiment. Some of them were paid for their participation, but were not told of their compensation until after the experiment. Each set of male and female subjects was divided into two groups (agent group and recipient group), each of which was instructed to pay attention to agent and recipient respectively. There were twelve, eleven, ten, and eleven

subjects in the male-agent, female-agent, male-recipient, and female-recipient groups respectively.

Stimulus and Procedure: The stimuli and procedure in experiment 2 were identical to those of experiment 1, except that subjects were instructed to pay attention to either agent or recipient in collision events.

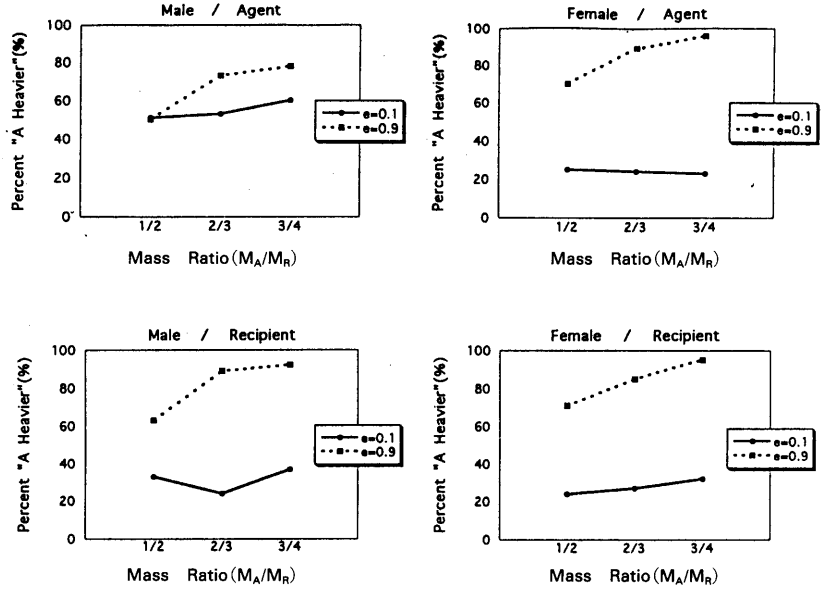

Fig. 5. Results of Experiment 2. The percents "A(Agent) Heavier" for each gender and object of attention obtained from the subjects who were instructed to pay attention to agent or recipient(Agent or Recipient group), are plotted as a function of mass ratio.

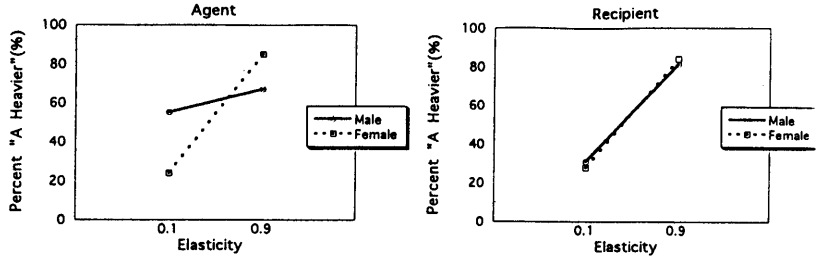

Fig. 6. Results of Experiment 2. The percents "A(Agent) Heavier" for each object of attention averaged over mass ratio, are plotted as a function of elasticity. These graphs are made for comparison with the prediction shown in Fig. 2.

RESULTS

The results of experiment 2 were graphed in Fig. 5 and Fig. 6, as in experiment 1. Both graphs represent the same results, except that performance data (the percent "A Heavier") were averaged over mass ratio in Fig. 6. Four factorial ANOVA (between-subject variable: gender, object of attention within-subject variable: elasticity, mass ratio) was run on the combined data of experiment 1 and 2. The data of the subjects who reported the use of the Final Speed Hypothesis or who could not articulate their own heuristics were excluded from analysis lest the results should be made unclear and difficult to interpret, because the purpose of this experiment was to examine whether attention to agent or recipient could lead to the use of the Direction Hypothesis or Initial/Final Speed Hypothesis respectively. Consequently, the number of subjects whose data were analyzed was nine, ten, eleven, ten, nine, and ten for the male-no instruction group, female-no instruction group (experiment 1), male-agent group, female-agent group, male-recipient group, and female-recipient group (experiment 2), respectively. The following factors and interactions were significant: elasticity ($F(1,53) = 64.04$, $p < 0.01$), mass ratio ($F(2,106) = 48.25$, $p < 0.01$), and their interaction ($F(2,106) = 40.71$, $p < 0.01$)[4]. Subordinate tests revealed that significant differences due to mass ratios were found on all pairs of data when $e = 0.9$, while only between $M_A/M_R = 1/2$ and $M_A/M_R = 2/3$ when $e = 0.1$ ($p < 0.05$, see Fig. 3 and Fig. 5).

Furthermore, nonparametric tests were run on the distributions of the sample data when $e = 0.1$ to examine the effect of gender and object of attention in more detail. Figure 7 represents, for each group, the frequency distribution of the percent "A Heavier" when $e = 0.1$. Three data for mass ratios were obtained from each subject, so the sample number of each panel in Fig. 7 is 3 times the number of subjects in each group. The data when $e = 0.9$ were excluded from analysis, because, as described above, apparently greater effects of mass ratio could be found than when $e = 0.1$.

Effects of object of attention: For each gender, two sample two-tailed Kolmogorov-Smirnov tests were run on all pairs of the distributions for three objects of attention mode (no instruction–experiment 1; agent, recipient–experiment 2) to examine their effects on the use of heuristics. Significant differences were found in the following pairs: for male, no instruction v.s. agent ($p < 0.05$), agent v.s. recipient ($p < 0.05$); for female, agent v.s. recipient ($p < 0.01$).

Effects of gender: For each object of attention, two sample two-tailed Kolmogorov-Smirnov tests were run to characterize gender differences of the distributions. Significant gender difference was found only for agent group ($p < 0.01$).

4. The interaction of gender × elasticity was marginal ($p = 0.0598$) and, by subordinate tests, gender difference was marginal only when $e = 0.1$. Further analysis of the interaction of gender × object of attetion × elasticity revealed that the main effect of elasticity was not significant only for the male-agent group (see Fig. 6).

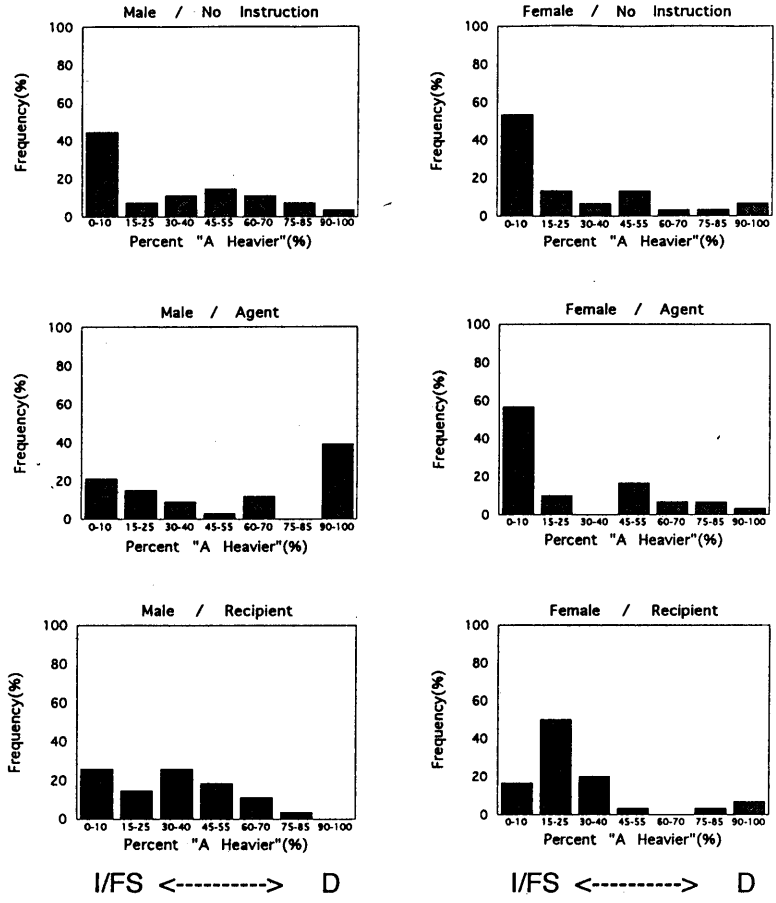

Fig. 7. The frequency distributions of the percents "A(Agent) Heavier" when e = 0.1 for each gender and object of attention, obtained from experiment 1 (No Instruction) and 2 (Agent or Recipient). Three data for mass ratios were obtained from each subject. Therefore, the sample number of each panel is 3 times the number of subjects. Higher and lower frequency of percent "A Heavier" means the frequent use of the Direction Hypothesis and Initial/Final Speed Hypothesis respectively.

Discussion

Figure 6 shows sharp rises of the percent "A Heavier" from when e = 0.1 to e = 0.9, except for a gradual rise for the male-agent group. The comparison between these patterns and prediction shown in Fig. 2 suggests that the Initial/Final Speed Hypothesis was used for relative mass judgements in most cases. Furthermore, elaborate surveys of the frequency distributions of the data(the percent "A Heavier"), when e = 0.1 for each subject group,

revealed that significant differences were found for males between agent group and the others, and for females between recipient group and the others, and between males and females only for agent group. The differences between female subjects could be considered due to the minimal shift of distribution peaks to the right side of the graph for recipient group (see the right panels of Fig. 7). However, the distribution pattern for each object of attention was approximately identical, skewed to the left side of the graph. It follows from these results that, in any case, most female subjects used the Initial/Final Speed Hypothesis for relative mass judgements.

However, it does not hold for the other significant differences between the distributions. All of them were found in comparisons including the distribution of the male-agent group, for which the distribution pattern had two peaks on both the right and left sides (quite different from those for the other groups). The bimodality of the distribution suggests that male subjects paying attention to agent used the Direction Hypothesis and Initial/Final Speed Hypothesis half-and-half for relative mass judgements.

General Discussion

Effects of attention to a specific object

We found in this experimental study that, on some restricted condition, the instructed attention to a specific object (agent/recipient) affected the use of heuristics for relative mass judgements in collision events: some male subjects paying attention to agent used the Direction Hypothesis more often than the others, while those paying attention to recipient, whether male or female, showed the same performance as the control subjects in experiment 1. The latter finding might probably be due to the ceiling effects, for most control subjects, even though not instructed to pay attention to a specific object, originally used the Initial/Final Speed Hypothesis which is supposed usable by paying attention to recipient. Then, why did they use the Initial/Final Speed Hypothesis so often? One reason derived from our assumption of this study might be that the recipient was paid more attention to than the agent generally, even though not instructed to be payed attention to. For example, it might be payed attention to for its informational simplicity. In this study, the recipient began to move unidirectionally only after collision, while the agent continued to move throughout pre- and postcollision periods, and could either go forward or ricochet after collision. In other words, the recipient's motion was informationally very restricted, both spatially and temporally.

Thus, subjects had to concentrate only on its postcollision velocity when they watched it, so that they could save costs in processing efficiency and perform in less time, as Todd and Warren (1982) argued for the advantages of heuristics. Otherwise, the recipient might be perceived and payed attention to as such. It has been known that differentiation between agent and recipient is made at a preverbal stage (Golinkoff, 1975; Golinkoff & Kerr, 1978; Mandler, 1992). This differentiation is also significant after adulthood is reached. It is possible that the recipient was paid more attention to for some reason.

A second possible reason is that the Initial/Final Speed Hypothesis itself sounded more

valid for our subjects. As Gilden(1991) pointed out, speed and angle(direction) could be classified as continuous and categorical variables respectively. This definition holds in this experiment where the agent could have no alternative but to go forward or to ricochet after collision. "Categorical" means digital, so the judgements based on direction are done in an all-or-none way. However, not all various and complex phenomena in the real world can be explained by such a distinction as A v.s. non-A. This default(of direction as information) might make it difficult for our subjects, whether intentionally or not, to use the heuristic method based on it, namely the Direction Hypothesis, and make it easy for our subjects to use the Initial/Final Speed Hypothesis.

Gender Differences

As described above, gender difference was significant only for agent group: more male subjects used the Direction Hypothesis for relative mass judgements in collision events than did female subjects. Considering the cause of this effect as the issue for heuristics themselves, it would be important to discriminate between two attributes of heuristics, as proposed in our previous study(Sato, 1991). One is accessibility(regarding whether we can be aware of one heuristic method), and the other is utility(regarding whether it can actually be used for problem solving, leading directly to performance). As to accessibility, about the same percentage of male and female subjects in the agent group reported that they were aware of the Direction Hypothesis. Therefore, it is difficult to attribute the gender difference to heuristics' accessibility. Instead, it would be better if explained by means of heuristics' utility. As described in the previous clause, Direction Hypothesis is categorical(digital)in character in this study, which is supposed to make it difficult to be used as a general rule. Male subjects might not worry about this point, or might be rather familiar with this all-or-nothing way of reasoning. Another possibility is that they might be more sensitive to task demands. In other words, they might intentionally use the heuristic method associated with the agent to which they were instructed expressly to pay attention. Still, gender difference was also found in our previous study that dealt with developmental change of the heuristics used for relative mass judgements in collision events(Sato, in press). It showed that students in their first few years of elementary school were in a transition period where the Initial/Final Speed Hypothesis was gradually replacing the Final Speed Hypothesis(which was dominant in preschool subjects), and that, at this age, more females than males had adopted the Initial/Final Speed Hypothesis.

This might also suggest gender difference regarding cognitive judgements. Further research is needed in lieu of generalizing from these findings.

Correspondence between performance and verbal reports

Finally, we will refer to the problem regarding the correspondence between subjects' relative mass judgement performances and their verbal reports about the heuristics they used. Though not the main topic in this study, it is a rather important problem. Our experiments were premised on their correspondence: We predicted subjects' performances with reference to

their verbal reports in our pilot study. However, as discussed by Nisbett and Wilson (1977) or Ericsson and Simon (1980), performances and verbal reports involved in our various activities do not necessarily reflect each other directly and accurately. Specifically, Gilden(1991) pointed out, in his elaborate review regarding dynamical awareness, that "self-reports do not indicate the nature of perceptual processing"(p.556). Indeed, our developmental study(Sato, in press) revealed that preschool subjects, who could judge relative mass to almost the same ability as adults, could not always articulate their heuristics. In this study, even adults reported that they had not been aware of their heuristics until about a third of the experimental session had passed, in spite of the general stability of their performances from the beginning. Thus, we might say that, at least in some cases, performances of relative mass judgements were not justified by our verbal consciousness. Further research is also needed to examine this point.

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